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A Prototype Dynamics Decision Making Model of Mining Feasibility Study on Investment

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Abstract: *This article develops a prototype dynamics decision making model of mining feasibility study on investment. It is a core model of developing the decision making tool of mine planning system by using economic theories including, Net Present Value (NPV) and Internal Rate of Return (IRR) [1-3, 6].*

Generally; the way to calculate NPV and IRR, we use spreadsheet software. It is quite slow and inflexible, when we want to compare in many scenarios. Thus, the aim of this article is to develop a prototype system dynamics model by using Vensim Software. It can be a faster and more flexible calculation tool of discount cash flow. In this article, the prototype model can show results in many scenarios correctly and rapidly. The successful of this model show ability to simulate many scenarios in the short time by changing a single or multiple input variables. Furthermore, the prototype model will be more developed by extending variables such as cost estimation, price analysis etc., and also will be verified by more case studies of mining in the future.

Therefore, the prototype model can be used to decide on investment in mining project alternatively. Moreover, in the future this prototype model will be not only further developed to be a decision making tool for coal mine planning system, but also can apply to other type of mining.

Keywords: System Dynamics Model, Coal Feasibility Study, Decision Making

1. Introduction

Decision on investment in mining is the first important step of profit or loss the money in the mining business. Normally, the most famous tools in the economic decision on investment are the analyses of discount cash flow along period of mining by using Net Present Value (NPV) [1] and Internal Rate of Return (IRR) [2]. However, it's quite hard and take a lot of time to use a calculator for Solving equations of NPV and IRR in many conditions. Thus, the computer softwares are used to solve the problems. The one of a popular Software to calculate NPV and IRR is Spreadsheet Software, such as MS Excel. On one hand, the Excel quite useful because it has batch functions of NPV and IRR to help the user. On the other hand, the batch calculations accepts a value a time. Thus, in the general case of complex and continuously changing variables like in mining investment, the Excel is

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not the best way. Therefore, the system dynamics model [4] is a good alternative choice to solve the problems in the case of able to continually changing multiple variables.

A prototype dynamics decision making model of mining feasibility study on investment was created to be a decision making tool. It was developed by using Vensim software [5]. The result of calculation can be used to decide on investment in mining project.

2. Literature Reviews

2.1 The Decision Making on Investment Theory

The analysis of discount cash flow is a way to decide on investment in mining business. In case of the value of money changed all the time, the money tomorrow is not as valuable as money today [6], so the money in the future need to be calculated the value back to present for the same rule of comparison. The equations of PV and NPV show below [1].

PV Equation: [1]

$$PV = \frac{R_t}{(1+i)^t}$$

where

t = the time of the cash flow

i = the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)

R_t = the net cash flow (the amount of cash: inflow - outflow) at time t. For educational purposes, R_0 is commonly placed to the left of the sum to emphasize its role as (minus) the investment. Sometime, the name, future value (FV) is used.

NPV Equation: [1]

$$NPV = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

NPV is an indicator of how much value an investment or project adds to the firm. With a particular project, if *Rt* is a positive value, the project is in the status of discounted cash inflow in the time (*t*). If *Rt* is a negative value, the project is in the status of discounted cash outflow at the time (*t*). Appropriately risked projects with a positive NPV could be accepted. This does not necessarily mean that they should be undertaken since NPV at the cost of capital may not account for opportunity cost, i.e. compares with other available investments. In financial theory, if there is a choice between two mutually exclusive

alternatives, the one yielding the higher NPV should be selected [1].

The internal rate of return (IRR) on an investment is the "annualized effective compounded return rate" or discount rate that makes the net present value (NPV) of all cash flows (both positive and negative) from a particular investment equal to zero [2].

IRR Equation: [2]

$$NPV = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t} = 0$$

Because the internal rate of return is a rate quantity, it is an indicator of the efficiency, quality, or yield of an investment. This is in contrast to the net present value, which is an indicator of the value or magnitude of an investment [2].

An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital [2].

2.2 The System Dynamics Theory and Application

System Dynamics (SD) which founded by Prof. J.W. Forrester in 1950 [4], is a theory of system structure and a set of tools for representing the structure of complex systems and analyzing their dynamic behavior by computer modelling. It has many commercial softwares supported an SD model. Vensim software [5] is one of the most popular software used to develop the SD model. Moreover, Vensim software also has a free version for the user. In Fig 1 shows the generic structure of an SD model created by Vensim software.

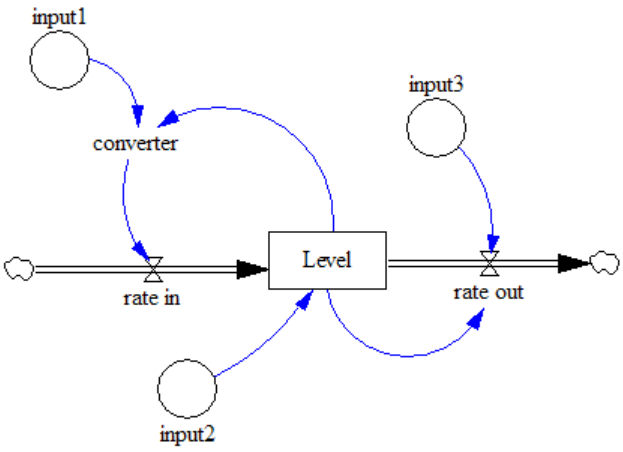

Figure 1: Simple SD Model structure

3. Research Methodology

3.1 Simple Flow Diagram of the Model Processing

This prototype SD model was developed without the costs of royalty and tax, then a simple processing diagram of the prototype SD model is shown in Figure 2.

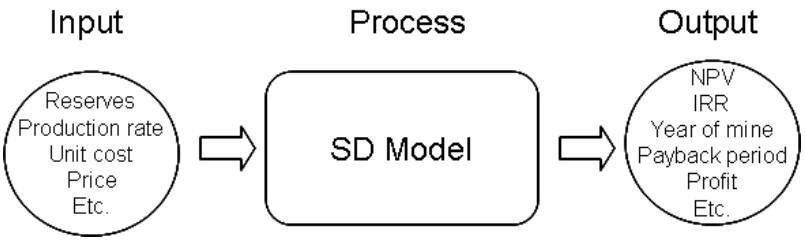

Figure 2: Processing diagram of the prototype dynamics decision making model of mining feasibility study on investment

3.2 Case Study Condition

The south of Thailand has a lignite reserve around 324,000,000 tons, Assume the rate of return equal 0.15 (15%), the unit cost of investment per production planning around 100 dollars/ton, the unit operating costs around 5 dollars/ton, and the price of lignite around 17 dollars/ton.

3.3 Scenario Simulation

There are 3 variables were varied for calculating NPV in the case study, including (1) Production Rate, (2) Price of Ore, and (3) Unit Operating Cost. Then, the 27 scenarios were calculated. Moreover, an average condition for IRR is the price of ore steady at 17 dollars/ton, production rate 17.5 million tons, and unit operating cost 5 dollars/ton. The metrics input variable conditions are shown in Table 1.

Table 1: The metrics input variable conditions

Items	Value 1	Value 2	Value 3	IRR conditions
Price of Ore ($/ton) [symbol : P]	Decline trend (0.5$/year) [symbol: Pd0.5]	Steady (17$/ton) [symbol: Ps0]	Incline trend (0.5$/year) [symbol:Pi0.5]	17 [symbol: Ps0]
Production Rate (Mi.ton/year) [symbol : Q]	15 [symbol: Q15]	17 [symbol: Q17]	20 [symbol: Q20]	17.5 [symbol: Q17.5]
Unit Operating Cost ($/ton) [symbol : Oc]	3 [symbol: Oc3]	5 [symbol: Oc5]	7 [symbol: Oc7]	5 [symbol: Oc5]

Note: *Example scenario of IRR condition is Ps0_Q17.5_Oc5, it means the price of ore 17 dollars/ton (Ps0), production rate 17.5 million tons (Q15), and unit operating cost 5 dollars/ton (Oc5).*

4. Results

4.1 Model Structure

The SD model structure of a prototype dynamics decision making model of mining feasibility study on investment shows in Figure 3.

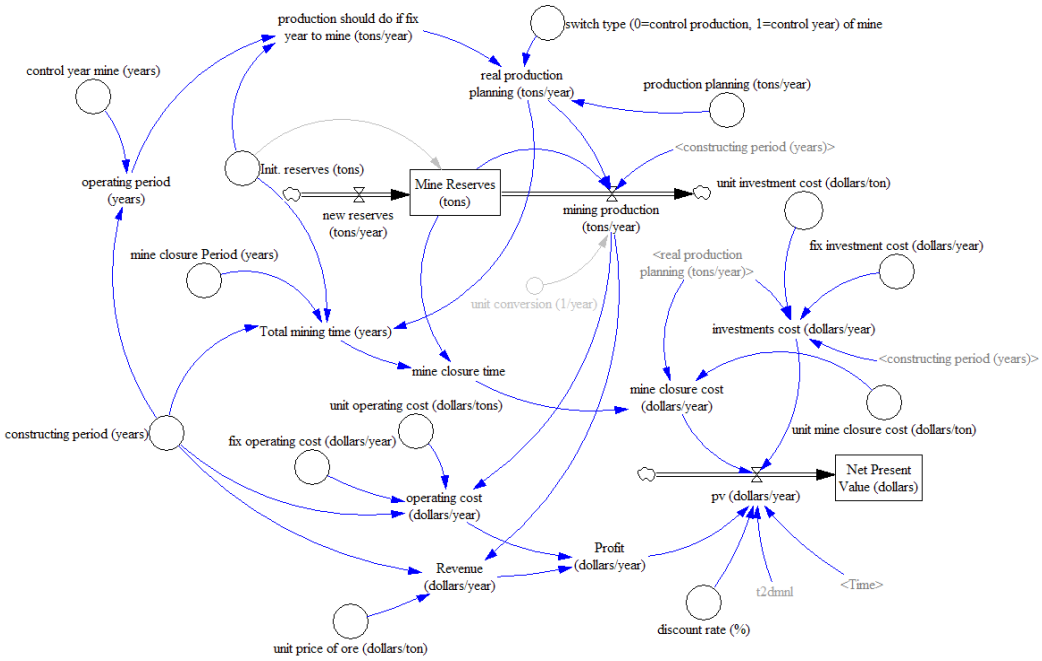

Figure 3: The SD model structure of a prototype dynamics decision making model of mining feasibility study on investment

4.2 Simulation Results

The prototype SD model can show the calculation result when changed the values of input variables. In the case of the trend of lignite price goes down with the rate 0.5 dollars/year (scenarios No. 1 to 9), we found that 6 cases of NPV results are negative. In contrast, if the price of lignite is steady at 17 dollars/ton, or has an inclined trend with the rate 0.5 dollars/year (scenarios No. 10 to 27). The NPV results show positive in all cases. Moreover, the average NPV of all scenarios is around 29.6×10^7 dollars, see details in Table 3.

In the case of IRR value, the average scenario condition makes the positive result of IRR of investment around 21%, the result shows in Table 2.

Table 2: Summary result of IRR in average condition

No.	Scenarios symbol	NPV ($x10^7)	IRR (%)
28	Ps0_Q17.5_Oc5	0	21.05

Table 3: Summary Result of NPV in 27 Scenarios

No.	Scenarios symbol	NPV ($x10^7)	No.	Scenarios symbol	NPV ($x10^7)
1	Pd0.5_Q15_Oc3	13.87	**15**	Ps0_Q17_Oc7	11.59
2	Pd0.5_Q15_Oc5	-2.66	**16**	Ps0_Q20_Oc3	51.01
3	Pd0.5_Q15_Oc7	-19.2	**17**	Ps0_Q20_Oc5	30.23
4	Pd0.5_Q17_Oc3	15.08	**18**	Ps0_Q20_Oc7	9.46
5	Pd0.5_Q17_Oc5	-3.25	**19**	Pi0.5_Q15_Oc3	76.36
6	Pd0.5_Q17_Oc7	-21.59	**20**	Pi0.5_Q15_Oc5	59.82
7	Pd0.5_Q20_Oc3	15.76	**21**	Pi0.5_Q15_Oc7	43.28
8	Pd0.5_Q20_Oc5	-5.02	**22**	Pi0.5_Q17_Oc3	81.44
9	Pd0.5_Q20_Oc7	-25.79	**23**	Pi0.5_Q17_Oc5	63.11
10	Ps0_Q15_Oc3	45.12	**24**	Pi0.5_Q17_Oc7	44.77
11	Ps0_Q15_Oc5	28.58	**25**	Pi0.5_Q20_Oc3	86.26
12	Ps0_Q15_Oc7	12.04	**26**	Pi0.5_Q20_Oc5	65.49
13	Ps0_Q17_Oc3	48.26	**27**	Pi0.5_Q20_Oc7	44.71
14	Ps0_Q17_Oc5	29.93	**Average**		29.58

5. Conclusion and Discussion

The prototype dynamics decision making model of mining feasibility study on investment can help to decide on investment by calculating discount cash flow along period of a project rapidly. So, it's a faster and more flexible alternative tool. Furthermore; in the case study conditions, the average NPV results around $29.6x10^7$ dollars, and IRR of this case study was around 21%.

For the further development, this prototype model will verify with more case studies and add more sub-systems, etc. Therefore, the prototype dynamics decision making model of mining feasibility study on investment will apply to be a decision making tool on the mine planning system in the future.

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